

# Origin of universes with different properties

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The concept of a random Lagrangian is proposed. It is considered as a basis for a new view of the old problems such as renormalization, nonzero vacuum energy and the anthropic principle. It gives rise to nontrivial consequences both in cosmology and in particle physics. It is shown that some of them could be checked in the nearest future. Scalar-tensor models of gravity are a direct and necessary consequence of this approach.

## 1 Introduction

The common way of the development of physics is supported by a large amount of observational and experimental data. On the other hand, some phenomena which we expected to be discovered for a long time are still only hypotheses. Other data, being very impressive, are not yet explained. As an example, worth mentioning are the existence of dark matter and dark energy, superhigh energy particles in cosmic rays and the “bursts”, i.e., almost instantaneous energy explosions with an energy release of the order of  $10^{53}$  erg. These astrophysical data specify the presence of new phenomena to be comprehended.

One of the cornerstones of modern microphysics is the Weinberg-Salam model of the electroweak interaction. Its success became evident after the discovery of the  $W^\pm$  and  $Z$  bosons. Meanwhile, another prediction of this model, the existence of Higgs particles, is not yet confirmed. Their detection in modern accelerators would specify the properties of the model and point out the direction of further development.

One could conclude that cosmology and microphysics stand before quantitative progress which should reconcile the theoretical studies with the essentially new experimental data. It makes sense to analyze the basic postulates which underlie every modern theory.

A widespread approach consists in choosing dynamical variables and a form of a Lagrangian from the beginning. It is supposed that the smaller is the number of parameters the better is the quality of a theory. This approach, being successful in areas of specific calculations, suffers from some problems. These problems are rarely discussed and usually are even not mentioned. Indeed, let us suppose for a minute that somebody succeeded in his attempts to create a theory explaining all experimental data. It does not mean the end of physics. On the contrary, it becomes absolutely clear that several general questions should be resolved:

(A) What mechanism is responsible for the specific form of a potential with particular values of the parameters? In particular, why do we suppose that the minimum of the potential is exactly zero?

(B) To which extent the quantum corrections deforming the shape of the potential are important?

(C) The question of renormalizability of a theory appears not to be so simple if one takes into account the interaction of particles with gravitons. The latter is usually extremely small and surely should not be considered in real calculations, but its existence is of principal importance. Gravity, being a non-renormalizable theory, leads to the same property of any theory connected with it.

These problems are not very important for low-energy physics, and the scientists usually wave them away. But modern accelerators have reached rather high energies of the order of 1 TeV and higher. Not only the experimentalists, but the theorists as well feel the necessity of dealing with a new level of energies: theories of the early Universe operate with Planck densities.

Problem (A) became topical after the discovery of dark energy [1], which could be explained most easily as a nonzero vacuum energy density. The latter, being  $\sim 120$  orders of magnitude smaller than Planck scale, allows the formation of the large-scale structure of our Universe. This problem, or more widely,

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the problem of creation of the Universe with the observable properties, has attracted attention of many scientists and caused a prolonged discussion [2, 3]. This discussion continued until recently [4, 5, 6, 7, 8].

The anthropic principle plays a significant role in the discussion of the problem of fine tuning of the Universe parameters and, in particular, the problem of a nonzero dark energy [5, 6, 9, 10, 11]. In general, this principle suggests the existence of a set of universes with different properties. Some of them are similar to our Universe. The others, in fact, a dominant majority, are not suitable for life formation. “The only thing that remains” is to create a theory which could base the existence of such a set of universes. In this paper we argue that modern quantum field theory supplies us with the necessary ingredients for solving this problem.

Neglecting quantum corrections (problem (B)) seems doubtful at high energies. Moreover, new terms in the Lagrangian appearing due to quantum corrections are used creation of inflationary models [12] and particle models [13]. It is evident that quantum corrections carry on a double meaning. On the one hand, they lead to a significant uncertainty of predictions of any inflationary model. On the other hand, the same corrections give new possibilities for particle models and hence for models of the early Universe tightly connected with them.

A new approach is proposed in this paper. It is supposed *a priori* that the contribution of quantum corrections to a Lagrangian must not be neglected. This supposition permits one to validate the existence of universes with different properties and look from another side at the problems listed above. It is shown that an experimental test of the suggested approach is possible on the basis of modern accelerators.

## 2 Deformation of a potential

According to the previous discussion, any fixing of the shape of a potential leads inevitably to problems (A)–(C) listed in the Introduction. On the other hand, our Universe has been formed at very high energies where the contribution of the quantum corrections was important. Evidently, the potential acquires a much more complex form, compared with the original choice, due to quantum corrections. If we restrict ourselves to scalar fields  $\varphi$ , naive calculations of the quantum corrections lead to a potential in the form of an infinite set

$$U_{qc}(\varphi) = \sum_k^{\infty} a_k \varphi^k.$$

Generally speaking, negative powers are not excluded. Unfortunately, calculation of the coefficients  $a_k$  is waste effort for two reasons. Firstly, it is hard to believe that this decomposition is correct at large values of the field  $\varphi$ . Secondly, each term of this sum is a result of superposition of interactions with particles of every sort. Their contributions vary unexpectedly with increased degree of a term. Consequently, any information about the shape of the potential in the vicinity of a chosen field value  $\varphi_0$  is useless at  $\varphi \gg \varphi_0$ .

Thus any model of elementary particles with a specific form of the potential postulated from the beginning with a small number of parameters is doomed to failure at large values of the dynamical variables. As a possible solution of the problem, a new postulate is proposed. The latter is an analogue of the concept of attenuation of correlations known in statistical physics. As in the latter, the probabilistic approach used below allows one to obtain new results and to clarify the already known problems.

Let us first of all introduce the concept of probability density  $P(V; \varphi)$  of finding a specific value  $V$  of the potential at a given field value  $\varphi$ . It is supposed that the functions  $V(\varphi)$  and  $\varphi(x, t)$  are smooth enough except a discrete set of points. Then the only requirement to the form of the potential is expressed as the following postulate:

(\*) *Let the value of the potential  $V_0$  be known at a given field value  $\varphi_0$ . Then there exists such a value  $\Phi$  ( $0 < \Phi < \infty$ ) that, for any  $V$  and  $\varphi$ ,  $P(V; \varphi) > 0$  provided  $|\varphi - \varphi_0| > \Phi$ .*

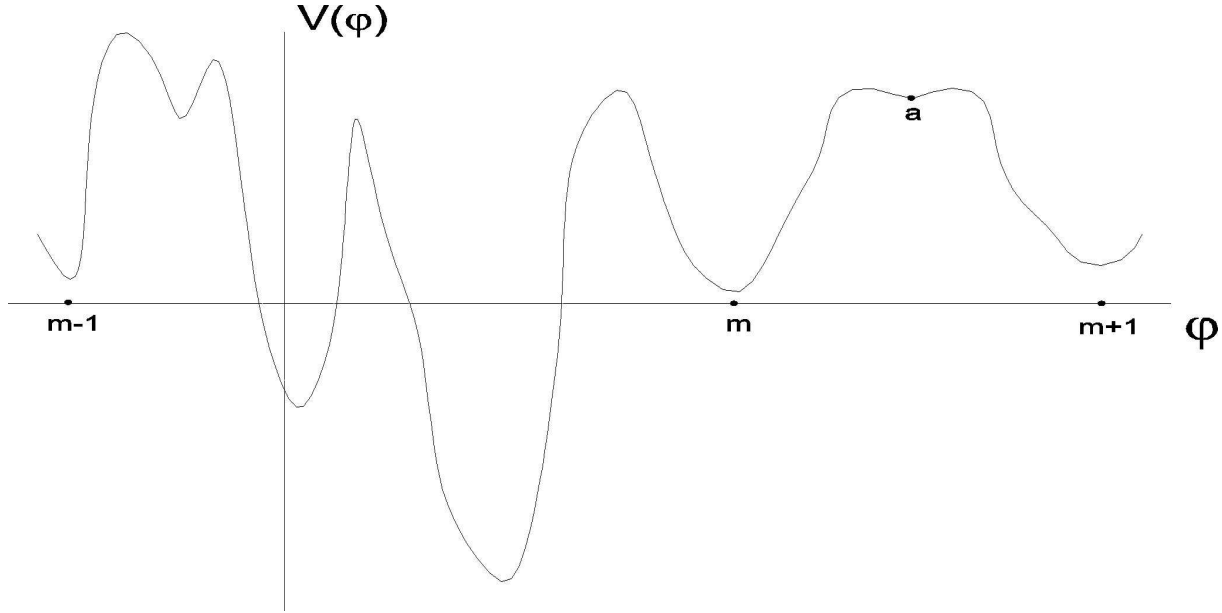


Figure 1: Characteristic form of the potential discussed in the text. Points mark minima where universes of different sorts are formed and evolve. Causal connection between the universes is absent.

The value  $\Phi$  depends on specific values of the potential  $V_0$  and the dynamical variable  $\varphi_0$ . As we shall see later, the only important thing is its finiteness, as is mentioned in the postulate. The transition to a probabilistic description is a cornerstone of this approach. It makes our possibilities much richer, as has happened in the transition from the classical description to the quantum-mechanical one. It is worth emphasizing that the form of the potential is not postulated from the beginning. Instead, only one, rather general property of the potential is proposed. Nevertheless, this property leads to multiple consequences which may could be experimentally tested. As we will show below, some of them could be performed in the nearest future, validating or invalidating the postulate.

Let us now discuss the general corollaries of the postulate (\*). The first direct corollary is that such a potential possesses a countable set of zeros. Indeed, if we make the inverse supposition, then, starting from some field value  $\bar{\varphi}$ , the function  $V(\varphi)$  is only positive or only negative for  $|\varphi| > \bar{\varphi}$ . Consequently,  $P(V < 0) = 0$ , or  $P(V > 0) = 0$  in this case, which contradicts the postulate (\*). It is obvious that a countable set of zeros implies a countable set of extrema of the potential.

To proceed, let one know that some minimum of the potential takes place at the field value  $\varphi = \varphi_m$ . Then, according to postulate (\*), there is a probability  $P(V_m)dV_m > 0$  of finding the potential value in a given interval  $(V_m, V_m + dV_m)$ . It immediately follows that there exists a countable set of such minima in the interval in question. The figure shows a representative form of the scalar field potential within some interval. If one considers the scalar field as an inflaton, the universe formation takes place at the minima  $m-1, m, m+1, m+2, \dots$ . Hence, a transparent consequence of the postulate (\*) is prediction of a nonzero cosmological constant because the probability to find a local minimum with a preset energy density is zero.

The shape of this “random” potential is unique in the vicinity of each minimum and hence the process of inflation is unique as well. Minimum values of the potential (vacuum energy density) are materialized with some probability density which is nonzero for any values. Hence, there is a countable set of low-lying minima, which is a necessary, but not sufficient, condition for the formation of universes similar to our Universe.

The most unpleasant point is the occurrence of unstable areas with  $V < 0$ . A similar situation was

revealed and discussed earlier. For example, the quantum corrections from interaction with fermions can result in scalar field potentials unbounded from below (see, e.g., [14]). An accurate renormalization of a Higgs-like potential leads to new minima [15], some of them being unstable. However, the spatial areas with  $V < 0$  are not causally connected with the visible part of our Universe. It is a result of an initial inflationary period of evolution of the Universe when its size has increased up to  $\sim \exp(10^{12})$  cm in the modern epoch, many orders of magnitude greater than the size of the observable universe  $\sim 10^{28}$  cm.

The potential can be approximated by the first terms of a Taylor series. It can be easily written in the vicinity of one of the minima, say,  $\varphi_m$ :

$$V(\varphi) = V(\varphi_m + \phi) \simeq V(\varphi_m) + a\phi^2 + b\phi^4, \quad (1)$$

thus simulating various potentials, which are usually postulated from the beginning.

A logical extension of the previous discussion is the inclusion of matter and gauge fields. It needs a generalization of postulate (\*) to any parameters of the theory, which are deformed by quantum corrections.

(\*\*) *All quantities of the theory, which are deformed by quantum corrections, comply with postulate (\*).*

In a substantiation of this postulate it is possible to refer to the same reasoning that has resulted in postulate (\*). Here it is important to note, that, due to the quantum corrections, all parameters of the theory  $g_n$ ,  $n = 1, 2, \dots, N$ , ( $N$  is the number of parameters of the theory) turn into (random) functions of a scalar field  $g_n(\varphi)$ . The values of a scalar field  $\varphi_m$  deliver minima of the potential, but not of the functions  $g_n(\varphi)$ . The values  $g_n(\varphi_m)$  are considered as constants in ordinary low-energy physics.

### 3 Weinberg–Salam model

Let us consider modifications of the  $SU(2) \otimes U(1)$  Weinberg–Salam Standard Model (SM), caused by the postulates (\*) and (\*\*).

#### 3.1 Higgs field

The potential of the Higgs field  $\chi = \begin{pmatrix} \chi_1 \\ \chi_2 \end{pmatrix}$  is usually supposed in the form

$$V_{Higgs}(\chi) = \frac{\lambda}{4} \left( |\chi|^2 - v^2/2 \right)^2. \quad (2)$$

i.e., a nonzero vacuum average is postulated from the beginning. A pleasant gift of our postulates is that it is now unnecessary — quantum corrections lead to multiple minima of any potential, including the Higgs one. The problem is more complex because the Higgs field necessarily interacts with the inflaton (at least due to multiloop corrections), and we inevitably obtain a set with an infinite number of terms,

$$V(\varphi, \chi) = \sum_{k,n=0}^{\infty} a_{kn} \varphi^k |\chi|^{2n} \quad (3)$$

Application of postulate (\*) results in a potential of a complex form with a lot of extrema and valleys in various directions. Minima of the potential are situated at points with the field value  $(\varphi_m, v_m)$ ,  $v_m \equiv \sqrt{|\chi_m|^2}$ . One can see that there is no need to include a nonzero vacuum average artificially. Of course, the probability that two neighboring vacua appear to be symmetrical, as it takes place in the SM, is negligible. It should not disturb us for this symmetry is not an important feature of the model. In this connection, we would like to mention Ref. [16] devoted to the Weinberg–Salam model with two asymmetric vacua. One of them is located at the Planck scale.

### 3.2 Modernization of the Standard Model

The Weinberg–Salam model is described by the Lagrangian

$$\begin{aligned}
L &= L_{gauge} + L_{lept} + L_{scalar} + L_{int}; \\
L_{gauge} &= -\frac{1}{4}F_{\mu\nu}^i F^{i\mu\nu} - \frac{1}{4}B_{\mu\nu}B^{\mu\nu}; \\
L_{lept} &= \bar{R}i\left(\widehat{\partial} + ig'\widehat{B}\right)R + \\
&\quad \bar{L}i\left[\widehat{\partial} + i\frac{g'}{2}\widehat{B} - i\frac{g}{2}\tau^i\widehat{A}^i\right]L; \\
L_{scalar} &= \left|\left[\widehat{\partial} - i\frac{g'}{2}\widehat{B} - i\frac{g}{2}\tau^i\widehat{A}^i\right]\chi\right|^2 - V(|\chi|^2); \\
L_{int} &= -G\left[\bar{R}\chi^+L + \bar{L}\chi R\right],
\end{aligned} \tag{4}$$

with the notations

$$\begin{aligned}
F_{\mu\nu}^i &= \partial_\mu A_\nu^i - \partial_\nu A_\mu^i + g\varepsilon^{ijk}A_\mu^jA_\nu^k, \\
B_{\mu\nu} &= \partial_\mu B_\nu - \partial_\nu B_\mu. \\
V(|\chi|^2) &= \lambda(|\chi|^2 - v^2/2).
\end{aligned} \tag{5}$$

Here  $A$  and  $B$  are the gauge fields,  $L$  and  $R$  are the left and right fermions. The Higgs field  $\chi$  has the nonzero vacuum average  $\langle\chi\rangle = \frac{v}{\sqrt{2}}$ . The parameters  $g$ ,  $g'$ ,  $v$ ,  $G$  of the model are expressed in terms of observable values: mass of the charged  $W$  boson,  $M_W$ , mass of the  $Z$  boson,  $M_Z$ , the electron charge  $e$  and the Fermi constant  $G_F$ :

$$\begin{aligned}
M_W &= gv/2, \quad M_Z = \frac{v}{2}\sqrt{g^2 + g'^2}, \\
e &= \frac{gg'}{\sqrt{g^2 + g'^2}}, \quad G_F = \frac{1}{\sqrt{2}v^2}.
\end{aligned} \tag{6}$$

As was shown in Ref. [17], the renormalization procedure can be chosen in such a manner as to preserve the gauge invariance of the Lagrangian (4). That is why we restrict ourselves to studying the results of renormalization of the parameters  $g$ ,  $g'$ ,  $G$ . According to postulates (\*) and (\*\*), these parameters transform into random functions:

$$g, g', G \Rightarrow g(\varphi, |\chi|^2), g'(\varphi, |\chi|^2), G(\varphi, |\chi|^2). \tag{7}$$

The proof is just the same as for the random potential.

At the same time, the potential of the Higgs field  $V(|\chi|^2)$  acquires the form (3) due to the same postulates (\*), (\*\*).

Let us now discuss the last term in the expressions (4) describing fermion interaction with Higgs particles. It will be shown that it gives a nontrivial result, different from the SM prediction and capable of an experimental test. Replacement of the constants  $g$ ,  $g'$ ,  $v$ ,  $G$  with the functions (7) leaves a trace in an effective Lagrangian.

The expression  $L_{int}$  in the Standard Model permits one to obtain the fermion mass  $m_f$  uniquely related to the vacuum average  $v/\sqrt{2}$  inserted by hand,

$$m_f = Gv/\sqrt{2}. \tag{8}$$

If one takes into account that the parameter  $G$  is a random function of the field  $\varphi$ , the result appears to be rather different. Let us parameterize the Higgs doublet as usual:  $\chi = e^{i\Theta(x)}\begin{pmatrix} 0 \\ \chi_0 \end{pmatrix}$  where  $\Theta(x)$  is an

$SU(2)$  matrix to be removed from the final Lagrangian by a gauge transformation. As a result, the term in question is

$$L_{int} = -G(\varphi, (\chi^0)^2) \chi^0 \overline{f_R} f_L. \quad (9)$$

Let a minimum No.  $m$  of the potential (3) take place at the field value  $(\varphi_m, \chi_m^0)$  ( $\chi_m^0 = v/\sqrt{2}$  in the usual notations). The first terms in the Taylor expansion of Eq. (9) in powers of  $h = \chi^0 - \chi_m^0$  have the form

$$\begin{aligned} L_{int} &\simeq -\chi_m^0 \cdot G(\varphi_m, (\chi_m^0)^2) \overline{f_R} f_L - \\ &G_f h \overline{f_R} f_L, \\ G_f &= \frac{\partial G(\varphi_m, (\chi_m^0)^2)}{\partial \chi_m^0} \chi_m^0 + G(\varphi_m, (\chi_m^0)^2). \end{aligned} \quad (10)$$

The fermion mass

$$m_f = \chi_m^0 \cdot G(\varphi_m, (\chi_m^0)^2) \quad (11)$$

appears to depend on the number  $m$  of the specific minimum (see also [18]), in which the universe evolves.

The field values  $\varphi_m, \chi_m^0$  represent a minimum of the potential (3), but not the minima of the other functions like  $G(\varphi_m, (\chi_m^0)^2)$ . That is why the usual proportionality of the fermion mass  $m_f$  and its coupling constant with the Higgs particle is absolutely absent.

Another deviation from the SM could be found in the self-interaction couplings of the Higgs particles. For example, the constant of trilinear interaction in the framework of the Weinberg–Salam model is equal to  $\lambda_{hhh} = 3\sqrt{2}\lambda v$  in the zeroth order of perturbation theory and hence is proportional to the known vacuum average value  $v$ . A different prediction follows from the potential (3). This constant has the form  $\lambda_{hhh} = (1/6)\partial^3 V(\varphi_m, \chi_m)/\partial \chi_m^3$  and has no connection with the other parameters.

It becomes evident that this approach is able to restore the Weinberg–Salam model with the exception of interactions with the Higgs particles  $h$ . It is instructive to consider the part of the Lagrangian  $L_{lept}$  responsible for the interaction of leptons (electrons) with the gauge fields. After the standard replacement of the fields  $B_\mu, A_\mu^i$  with the physical fields  $W_\mu^\pm, Z_\mu, A_\mu$  one obtains [19]

$$\begin{aligned} L_{lept} &= C_1 [\bar{\nu}_e \gamma^\mu (1 - \gamma_5) e W_\mu^+ + h.c.] - \\ &- C_2 (2\bar{e}_R \gamma^\mu e_R + \bar{\nu}_e \gamma^\mu \nu_e + \bar{e}_L \gamma^\mu e_L) Z_\mu + \\ &+ C_3 (\bar{e}_L \gamma^\mu e_L - \bar{\nu}_e \gamma^\mu \nu_e) Z_\mu - e A_\mu \bar{e} \gamma^\mu e. \end{aligned} \quad (12)$$

The quantities  $C_i, e$  are expressed in a usual way in terms of the initial parameters

$$\begin{aligned} C_1 &= \frac{g}{2\sqrt{2}}; \quad C_2 = \frac{e}{2} \tan \theta_W; \quad C_3 = \frac{e}{2} \cot \theta_W, \\ e &= \frac{gg'}{\sqrt{g^2 + g'^2}}; \quad \tan \theta_W = g'/g \end{aligned} \quad (13)$$

and, according to (7), are functions of the fields  $\varphi$  and  $\chi$ . Both fields are located in the vicinity of some minimum of the potential (3), and we can restrict ourselves to the first terms in the Taylor expansion:

$$\begin{aligned} C_i &\simeq C_i(\varphi_m, \chi_m^0) + \frac{\partial C_i(\varphi_m, \chi_m^0)}{\partial \chi_m^0} h; \\ e &\simeq e(\varphi_m, \chi_m^0) + \frac{\partial e(\varphi_m, \chi_m^0)}{\partial \chi_m^0} h. \end{aligned} \quad (14)$$

The inflaton field is supposed to be rather massive, so that we can neglect any interaction with its quanta. Indeed, its value  $\sim 10^{13}$  GeV [20] is many orders of magnitude greater than the masses of ordinary

particles. The inflaton dynamics is important only at a very early stage of the Universe evolution, when the horizon size is smaller than the inverse inflaton mass  $1/m_{\text{inflaton}}$ . The first terms in the expansion (14) were determined experimentally as far as they are connected with the known parameters: the electron charge  $e$  and the Weinberg angle  $\theta_W$  according to Eqs. (13). The second terms are responsible for new vertices of interaction of the leptons with the Higgs field quanta  $h$ . More certainly, the vertices  $\bar{\nu}_e W e h$ ,  $\bar{e} e Z h$ ,  $\bar{\nu}_e \nu_e Z h$ ,  $\bar{e} e A h$  originate from the Lagrangian (12) and Eqs (13), (14) in the form

$$\begin{aligned} L'_{lept} = & \Gamma_1 [h\bar{\nu}_e \gamma^\mu (1 - \gamma_5) e W_\mu^+ + h.c.] - \\ & - \Gamma_2 (2h\bar{e}_R \gamma^\mu e_R + h\bar{\nu}_e \gamma^\mu \nu_e + h\bar{e}_L \gamma^\mu e_L) Z_\mu + \\ & + \Gamma_3 (h\bar{e}_L \gamma^\mu e_L - h\bar{\nu}_e \gamma^\mu \nu_e) Z_\mu - \Gamma_e h A_\mu \bar{e} \gamma^\mu e. \end{aligned} \quad (15)$$

The four coupling constants  $\Gamma_1$ ,  $\Gamma_2$ ,  $\Gamma_3$  and  $\Gamma_e$  are expressed in terms of two unknown parameters,  $B \equiv \partial g / \partial \chi_m^0$  and  $B' \equiv \partial g' / \partial \chi_m^0$ :

$$\begin{aligned} \Gamma_e &= \left(\frac{e}{g'}\right)^3 B + \left(\frac{e}{g}\right)^3 B', \\ \Gamma_1 &= \frac{1}{2\sqrt{2}} B, \\ \Gamma_2 &= \frac{1}{2} \frac{eg'}{g^2} \left(\frac{e^2 g}{g'^3} - 1\right) B + \frac{1}{2} \frac{e}{g} \left(\frac{e^2 g'}{g^3} + 1\right) B', \\ \Gamma_3 &= \frac{1}{2} \frac{eg}{g'^2} \left(\frac{e^2 g'}{g^3} - 1\right) B' + \frac{1}{2} \frac{e}{g'} \left(\frac{e^2 g}{g'^2} + 1\right) B. \end{aligned} \quad (16)$$

These coupling constants could be measured independently. On the other hand, they are connected with each other, as readily follows from (16):

$$\begin{aligned} \Gamma_2 &= \Gamma_e \frac{1}{2} \left(\frac{g}{e}\right)^2 \left(\frac{e^2 g'}{g^3} + 1\right) + \\ \Gamma_1 \sqrt{2} &\left[ \frac{eg'}{g^2} \left(\frac{e^2 g}{g'^3} - 1\right) - \frac{e}{g} \left(\frac{g}{g'}\right)^3 \left(\frac{e^2 g'}{g^3} + 1\right) \right], \\ \Gamma_3 &= \Gamma_e \frac{1}{2} \left(\frac{g}{e}\right)^3 \frac{eg}{g'^2} \left(\frac{e^2 g'}{g^3} - 1\right) + \\ \Gamma_1 \sqrt{2} &\left[ \frac{e}{g'} \left(\frac{e^2 g}{g'^3} + 1\right) - \frac{eg}{g'^2} \left(\frac{g}{g'}\right)^3 \left(\frac{e^2 g'}{g^3} - 1\right) \right]. \end{aligned} \quad (17)$$

These expressions give a theoretical prediction for the values of  $\Gamma_2$  and  $\Gamma_3$  provided the vertices  $\Gamma_e$  and  $\Gamma_1$  are determined experimentally. At the same time, the same vertices  $\Gamma_2$  and  $\Gamma_3$  could be measured independently for comparison with the theoretical result. The existence of new vertexes (15) obeying the relations (17) is a direct consequence of the initial postulates (\*) and (\*\*). On the other hand, they may be checked experimentally in the nearest future. For example, the properties of the Higgs bosons will be investigated in the modern accelerators. Such a possibility is discussed in Ref. [21] for  $e^+e^-$  annihilation at energies  $\sim 500$  GeV in the center of mass system. In case the Higgs bosons is discovered, it will allow us to validate or invalidate the relations (17) and hence the above postulates.

## 4 Discussion

In this paper, the new postulates (\*) and (\*\*) have been proposed. These postulates are used instead of strictly fixing the Lagrangian from the beginning. This concept gives rise to nontrivial consequences both

in cosmology and in particle physics. First of all, it allow one to prove the existence of a countable set of universes disposed in potential minima with different values of microscopic parameters. It serves as a necessary ingredient of the anthropic principle which permits one to explain the origin of a universe like ours.

The problems listed in the Introduction look quite solvable if one uses the probability language for formulation of the postulates. In this framework, the answer to problem (A) is: “there exist an infinite set of universes with different parameters in the vicinity of local minima. One could extract from this set of universes a subset with parameters close to those of our Universe. The minimal value of the potential is not zero. Meanwhile, there exists an infinite set of universes with sufficiently small values of the potential minimum. It is a necessary condition for nucleation and formation of a universe like ours”.

An additional pleasant property of the potential governed by the postulates is its absolute renormalizability (problem (C)). Indeed, it contains terms with any power of the scalar field from the beginning, and any quantum correction can be included in the Lagrangian parameters.

The answer to the question (B) is evident. It is quantum corrections that deform the potential and produce an infinite set of minima.

Postulates (\*) and (\*\*) necessarily lead to scalar-tensor theories of gravity. Indeed, if we wish to be consistent, we have to admit, according to postulates (\*), (\*\*), that the quantum corrections convert *all* parameters of a Lagrangian, including the gravitational constant  $G_N$ , into random functions. In this case, a general form of the Lagrangian can be readily written:

$$L = -\frac{F(\varphi)}{16\pi G_N}R + \frac{K(\varphi)}{2}(\partial\varphi)^2 - V_{ren}(\varphi). \quad (18)$$

An immediate conclusion from Eq. (18) is that Newton’s gravitational constant is only an effective one and varies in different universes enumerated by the number  $m$ :  $G_N(m) = G_{N,our}F(\varphi_m)/F(\varphi_{our})$  (the index ‘our’ relates to our Universe). Different sorts of such theories are discussed in, e.g., Refs. [22, 23, 24]. Their global properties are considered in Ref. [25].

An important thing is that, in spite of the generality and brevity of the postulates, they possess a predictive power, and some of their predictions may be tested in the nearest future. More definitely,

(a) new vertices of interactions of leptons, gauge fields and Higgs bosons appear in this framework. One-to-one connections (17) between them may be checked experimentally in the nearest future;

(b) a strict connection between fermion masses and the coupling constant of their interaction with scalar particles is absent. It could be very important for axion models because it strongly facilitates the limits following from the observational data [26];

(c) the trilinear interaction constant appears to be a free parameter, contrary to the prediction of the Weinberg–Salam Standard Model;

(d) the cosmological  $\Lambda$ -term is not zero. More definitely,  $\Lambda = Const$ , contrary to the quintessence models.

A serious argument against the proposed postulates would be strict a equality to zero of the cosmological constant because such universes have measure zero among others. The evidence that the cosmological constant is not zero is rather firm these days, but we still cannot exclude the opposite possibility. If the future observations indicate that, nevertheless,  $\Lambda = 0$ , it will make the postulates doubtful.

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